II.

Observations on the Development of Raia batis.

By JEFFRIES WYMAN, M. D.,
HERSEY PROFESSOR OF ANATOMY IN HARVARD COLLEGE.

Communicated January 27th, 1864.

The following observations relate mostly to the changes which a single species of skate undergoes in its outward form and structure during development. They are based upon the examination of a series of eggs, collected in the spring of 1851 and of the three subsequent years. The publication of them has been delayed in the hope that other specimens might be obtained which would make it practicable to give an account of the evolution of the internal organs. Having been disappointed in this, it was thought desirable to publish such results as have already been reached, believing that some of them, at least, are additions to the previous knowledge of the subject.

Egg case. — This singular structure has the general form of such parts in egg-laying Selachians. The whole case, in the species here described, is between six and seven inches in length, of a deep greenish-brown color, and composed of minute parallel filaments, which give it a striated appearance and a silky lustre. The central pouch (fig. 1, *a*), for the protection of the yelk and the embryo, is about two inches long, an inch and a half wide, bulges in the middle, and has a hollow, slender, curved horn projecting from each corner. The fore end of the pouch is deeply concave, and thickest, while the hinder is thin, nearly square, and ragged; it is from this part that the embryo escapes, after the separation of the upper and under walls from each other. The hinder horns project backwards as they lie in the oviduct, and are of about twice the length of those at the other end. The outer edge of each horn is the more rounded, and near the free end has an oblong slit (*b b′*) for

the inward and outward flow of the water which passes through the egg during incubation.

At the base of each fore horn is a slender projection or spur (*c*), about half an inch in length, the whole outer border of which breaks up into a series of silky filaments, and these are especially abundant near the free end. Similar filaments are given off from the whole border of the capsule, and all become tangled and woven together in such a manner as to form a broad and somewhat thick membrane on each side (*d*). This membrane was found entire only on cases taken from the oviduct, and on those newly laid. In all such, however, as have embryos somewhat advanced, it is more or less destroyed, and for the most part only tufts of it remain at the base of each horn. The object of it is not apparent, unless it be to assist in securing an anchorage, by the entanglement of its filaments with submarine plants or rough surfaces.

In a single instance, in the dissection of skates, an imperfect egg-case was found in each oviduct, the development of it having just begun.* The hinder horns and the hinder edge of the capsule were the only parts completed. They were contained in the glandular portion of the oviduct, which is quite thick during the reproductive season, and is mostly made up of very minute and slender follicles, of great length. From some of them fibrils protruded, identical in structure with those out of which the cases are made, and which, after being liberated, are doubtless moulded into the shape of these cases, and cemented together by some secretion from the oviduct. The horns are formed in grooves on either side of the duct, and the pouch for the yelk in the intervening space.† A careful examination of the ovary and oviduct in the above instance showed the singular fact, that, although some of the yelks were mature, none had as yet been detached from the ovisacs. This circumstance renders it probable, that, after the horny pouch is partially formed, the yelk descends and enters it, and that then the other portions are completed. If this supposition, based upon a single observed instance, were to be confirmed by further examinations, it would prove the existence of an interesting deviation from a rule among animals generally supposed to be without exception, viz. that the presence of the yelk in the oviduct is necessary before the formation of the egg-coverings can begin.

* For the specimen here referred to, as well as for several others which have given me important aid, I am indebted to my friend Dr. John Green of Boston.

† Aristotle was familiar with the eggs of Plagiostomes. See Hist. of Animals, Book VI. Section 10. Ruysch figures them for the first time in the *Thesaurus Animalium*, Pl. III. figs. 3 and 4, showing the embryo *in situ*. Cuvier ascribes the materials of the case to the follicles, and the form to the glandular surface. *Leçons*, Tome VIII. p. 90.

In none of the cases which we have examined have we found the fœtus surrounded either by a membrane or by albuminous matter, but in every instance the yelk and the embryo were fully exposed to contact with the water, which entered by the openings already described. An albuminous covering may have existed at an earlier period, and have been absorbed.

Yelk.—After the body of the embryo has become well defined, it is attached to the yelk by a slender umbilical cord about half an inch in length (fig. 2). The yelk has not the pyriform shape so common in other Selachians, but is nearly spherical, though somewhat flattened above and below. The cord has the length just mentioned only temporarily, and soon begins to shorten, and contracts until the fœtus rests once more upon the surface of the yelk (figs. 6 and 7). The two omphalo-mesenteric vessels, common to all vertebrates, carry the blood from the embryo to the yelk and back. The artery, a branch of the mesenteric (figs. 2 and 7, *a*), passes out beneath the head, over the front of the yelk, and descends to the under surface, giving off minute twigs to the right and left; but the trunk itself does not branch. Dr. John Davy,* in his observations on the development of the torpedo, although he figures a vein surrounding the vascular area in the younger specimens, yet makes no reference to it in the text. Agassiz has observed a similar vessel in the yelk of a dog-fish, and has for the first time pointed out its resemblance to the *sinus terminalis* of birds. Dr. Davy's figures, taken in connection with those here given, form a complete series. In the youngest of the specimens described by him the sinus is found on the upper surface of the yelk, and quite near the embryo; in the second, it has receded toward the sides, and the vascular area enlarged to a corresponding degree. In our specimens it is found on the under surface, is of a triangular form (fig. 3), and encloses only a small area. Eventually it contracts still further, and at last wholly disappears, and thus the entire surface of the yelk becomes vascular (figs. 6 and 7).

As development advances the yelk is gradually withdrawn into the cavity of the abdomen, as in birds; but the retraction does not appear to be quite complete in the skates until a short time after hatching. In one instance a fully formed skate taken from the egg-case had the yelk reduced to a small flattened mass about two lines in diameter. Very nearly the same condition existed in another, which was already hatched. In a third instance, where the young had been hatched for a longer time, the yelk had been wholly introduced into the cavity of the abdomen; but a con-

* Researches Anatomical and Physiological, Vol. I. p. 61.

siderable mass of it, still within the abdominal cavity, remained to be absorbed (fig. 11, *a*), where, as in the newly hatched chick, it serves as a reservoir of nourishment. Dr. Davy states that, in the torpedo, the young fish is nourished by the yelk for six weeks after birth. In all cases we have found the vitelline duct entering the intestine just above the spiral valve.

Form of the Fœtus. — The general form of the youngest specimens is long, slender, and gradually tapers to a point backward, as in fig. 2, and may be described in one word as eel-shaped. The head presents two rounded projections, one of them forward (figs. 4[a] and 5, *d*), forming the foremost part of the embryo; this is made by the protrusion of the optic lobes, and closely resembles the same part in the embryos of birds; the second (fig. 5, *e*) is directed downward, and contains the cerebral and olfactory lobes, behind which are the eyes. These last, which in the earlier stages, as in figs. 2, 4, 10, are on the same level with the surrounding parts, soon become remarkably prominent, as in fig. 8, where they remind us of the eyes of the young of Malleus. In the fully formed fish they are again reduced to nearly the same level with the adjoining integuments. As development advances, the optic lobes cease to form the most prominent part of the head, in consequence of a change of position of the cerebral hemispheres, which rise to the same level with the organs just mentioned, as the facial disk (figs. 7, 9, 10, *b*) advances beneath them. In fig. 6 the embryo has many of the features of a shark; and in fig. 8, with the expansion of the pectoral and ventral fins, it begins to take on the form of the skate. For further details the reader is referred to the different sections of this article.

Fins. — In the youngest specimen examined (fig. 2), a vertical fold of skin stretches along the middle line, from near the head almost to the end of the tail above, and from near the umbilical cord to the same point below. These folds do not pass beyond or become connected around the end of the tail. The dorsals (figs. 2 and 7, *c*) are formed by two vertical extensions of the upper fold, and in this early stage of their existence are placed midway between the base of the tail and its tip, which last tapers to a slender point. The anals (figs. 2, 7, and 9, *d*) are formed from a similar extension of the under fold, and are situated somewhat farther forward than are the dorsals. The first (fig. 6, *d*) grows very rapidly, and soon acquires a disproportionately large size; but the second (fig. 6, *d′*) is quite diminutive. Both upper and lower folds and fins have their edges bordered with follicles.

Both dorsal and anal fins undergo a very remarkable change as development advances. The first in the adult are found quite at the end of the tail, instead of the middle, as in the early stage. This change of relative position seems to be

effected in part by the more rapid growth of that portion of the tail which is in front of them, while that which is behind scarcely increases in size, and thus the fins are soon nearer the end than the middle. At the time of hatching, the terminal portion is still present (fig. 11, *c*); but subsequently it is either absorbed, or, what is not improbable, is covered by the extension of the dorsals backward.

The anal fins, the first of which, as already stated, attains to a remarkably large size, are gradually absorbed, and are wholly removed before the end of gestation. From the fact of these fins having a temporary existence in the skate, and a permanent one in many sharks, it is not improbable that they may be present in the embryos of all Plagiostomes. In the torpedo the dorsal fins seem to retain their primary or embryonic position, as they remain permanently in the middle of the tail; and Uraptera has the slender terminal portion behind the dorsals persistent, just as in the newly hatched *Raia batis.*

This development, temporary existence, and early removal of the anal fins, gives us another interesting example of the formation of parts which have no obvious use in the economy, and which must be regarded as having merely a morphological value. It falls into the same category with the caudal fin of the embryo of Pipa, which is never used, the teeth of certain Cetaceans, the inferior incisors of the female mastodon, which are all removed without being used, and the milk incisors of the Guinea-pig, which are shed *in utero.*

There is still another point of interest in the morphology of the tail of the species we are here considering; for although symmetrical, it does not at any period assume the heterocereal form, but retains permanently its primary embryonic or protocereal condition.

In this respect the skates hold a lower position than the sharks, nearly all of whom pass through the protocereal into the heterocereal stage.

The pectoral and ventral fins begin as slight ridges on either side, but each soon takes on the form of a half-oval disk (fig. 4, *a*, *b*). At first the two are nearly continuous in the same plane (fig. 4), but the pectorals (figs. 8 and 9, *a*) grow the most rapidly, gradually assume a somewhat oblique position, and in a short time partially cover the ventrals. None of the specimens were of a proper age to show whether or not the pectorals were formed first, as is the case with the fore limbs of all vertebrates whose development has been thus far studied. As they grow, they advance on either side of the head in the form of horns (figs. 8 and 9, *a'*), but by degrees the space between these horns and the side of the head is filled up, and thus the eyes and the persistent portion of the first branchial fissure are pushed to the upper surface, and

eventually the pectorals gain the foremost part of the side of the head, at the same time becoming united with the extended facial disk.

The tail, as the whole animal increases in size, becomes relatively very much shorter. In the earlier stages the body is only three sixteenths of the entire length of the embryo, but subsequently it is about one half that length, as will be seen by a comparison of figs. 7, 8, 9, and 11.

Mouth. — In the youngest embryos this has an elongated shape, is broadest at the fore part, and, contrary to what is usually the case in the embryos of other orders, has its longest diameter directed from before backwards, which circumstance gives it a very singular appearance (fig. 4[a]). Its borders are formed by the first branchial arch (figs. 4[a] and 5, *b*), and, as development advances, its longest diameter begins to shorten, and the arch bends on either side, its upper and lower, or its fore and hinder portions, forming an angle with each other; and thus begin the future angles of the mouth. That portion of the arch below these is without a doubt transformed into the lower jaw, and the "upper jaw" is formed of what remains in front of them.

The homology of this so-called upper jaw has led to much discussion. One thing is certain, there is at no time to be seen in the circumference of the mouth anything which corresponds with the "intermaxillary bud" or "fronto-nasal protuberance"; nor is there anything corresponding with an upper "maxillary bud." The only other parts to which the "upper jaw" could be said to correspond would be the palatines, as asserted by Cuvier; or more probably, as maintained by Mr. Huxley, the bones just mentioned, the pterygoids and quadrate bones together, all of which are believed to be developed from one and the same primary cartilage.

If the maxillary and intermaxillary bones exist at all in the head of the skate, their homologues must be found in the parts farther forward than those just mentioned, and in some way connected with the nostrils. We shall, therefore, speak of them when these last-named parts are described.

There is a very important change, which, though not directly connected with the mouth, yet involves the region of it, and may properly be mentioned here; namely, the formation, just in front of the nostrils, across the whole breadth of the under side of the head from one pectoral fin to the other, of a ridge of thickened integument, which gradually extends forward in a horizontal plane, forming what may be called the facial disk, and is most prominent in the middle (figs. 7, 9, and 10, *b*). It is by the extension of this forward till it passes beyond the foremost part of the cranium, and its fusion with the pectorals, that the pointed rostrum of the adult skate is formed (fig. 11, *e*). Even after this is nearly completed, the cranium remains prominent above it, but eventually both come to the same level.

In advanced embryos there is formed behind the mouth a semicircular fold of skin, which extends from one angle to the other, and very closely resembles the lower lip of mammals in its first stage of development. We did not find this in an adult specimen which was especially examined for comparison.

Nostrils. — In the adult, each nostril is lodged in an inverted cartilaginous cup connected with the base of the cranium, and lined with a folded sensitive mucous membrane. From this there extends to the angle of the mouth a deep groove, which ends just in front of the "upper jaw." The integument between the right and left grooves projects from the general surface, forming a sort of upper lip (fig. 11, *d*), and the angles are developed into fringed lobes which cover the corners of the mouth. Each lobe contains a cartilage, which Müller compares with the cartilages of the wings of the nose, as also the outer border of each groove opposite to them. The peculiar configuration of these parts in the adult skate, and the resemblance of the whole to an embryonic condition of the higher vertebrates, renders the study of them quite important. As Professor Agassiz states, "no one can fail to be impressed with this resemblance who compares the head of an embryo quadruped, looking at it in front face, with the adult skate." * To give demonstrative evidence that the parts thus compared are homologous, can only be done by an examination of a larger number of specimens, in different stages of development, than have as yet been studied. The series here described contributes something to this end, and enables us to determine some points which have not thus far been noticed.

The first traces of the olfactory fossæ which we have seen consisted of two small, but elongated and well-defined pits (fig. 5, *c*), somewhat enlarged at each end, and converging towards each other backward. They are at a distance from the mouth, and have no connection whatever with it, nor is there as yet the beginning of the groove which is found at a later period. In these respects they resemble the primary form of the nostrils of vertebrates in general. The position of them is such that they might be easily overlooked, for they are confined mostly to the hinder face of that portion of the head which is formed by the projection of the cerebral lobes downward, and can only be wholly seen by standing the embryo on its head. As the mouth takes its permanent shape, the nostrils lengthen, and a process forms on the inner border of each of them (fig. 10, *a*), which is the first stage of the lobe already described as existing in the adult. By a gradual thickening of the integuments, these processes become connected with each other across the middle line, when the whole skin between the nos-

* Methods of Study in Natural History, (Boston, 1863,) p. 317.

trils projects above the surface, and forms the upper lip, or the portion already spoken of as having so strong a resemblance to the intermaxillary bud or protuberance of the higher vertebrates (fig. 11, *d*). The edges of this form the inner borders of the nasal grooves, the outer ones being the result of a corresponding thickening of the integuments on the other side of this groove. Both inner and outer borders rise to the same level.

If now we compare the phases which these parts pass through in skates with the permanent conditions of them in other Selachians, it will be found that, in one species or another, these permanent conditions are arrests of development in various stages. In *Oxyrhina gomphodon* the nostrils retain permanently the primitive form of the olfactory fossæ, like that of the youngest skates noticed above; in *Pristiurus melanostoma*, and in *Mustellus*, *Carcharias laticaudus*, and many other species, the nostrils have superadded the lobe on their inner border, but no further thickening of the integument between them; in *Scyllium Bergeri* this lobe is extended by the thickening of the integument towards the middle line, as in Fig. 10; and in *Raia torpedo*, *Scyllium maculatum*, *Tæniurus Meyeri*, and others, it extends across the whole space between the nostrils, and forms above the mouth a continuous upper lip, as already described.

If the part the development of which has just been described is to be compared with the intermaxillary bud, the grooves on either side must be compared with the unclosed nostrils of the embryos of air-breathing vertebrates, or in other words to the "hare-lip." In air-breathing animals the nostrils open into the mouth, either by a canal between the maxillary and intermaxillary bones, as in many reptiles, or by a canal extending farther back, and separated from the mouth by the bones just mentioned and the palatines in addition, as in mammals; or by these bones and the pterygoids, as in the crocodiles. In the Proteus, Axolotl, and Menobranchus, however, the nostrils cannot be said to enter the mouth at all, but pass through the upper lip at a point corresponding with the union of the maxillaries and intermaxillaries, but still exteriorly to the dental arch. Bearing this in mind, we are led to look for the homologues of these bones in the immediate neighborhood of the nostrils in the skate. The only parts which occupy the position indicated are the cartilages, already referred to, contained in the nasal lobes, and in the parts just outside of the nasal groove. Is not the cartilage which extends from the olfactory fossæ towards the pectoral fin the homologue of a maxillary bone, and that in the lobe, of an intermaxillary? If so, the skates and Proteiform reptiles agree in having the nostrils open in front of the dental arch, but at a point corresponding with the union of the maxillaries and intermaxillaries; they differ in this, that while in all Batrachians the nasal groove becomes closed, in the skates it

remains permanently open. Should this prove to be a correct determination of the parts, it will add another feature which justifies Owen, Agassiz, and others, who have so far dissented from Cuvier as to give the Selachians a place in the zoölogical series higher than that of the bony fishes. At the same time, it will give corroborative proof of the correctness of Cuvier's view, that "the rudiments of the maxillaries, intermaxillaries, . . . are evident in the skeleton." * Furthermore, we may also assert that among Selachians we have numerous instances of a double hare-lip being a normal adult condition.

Branchial Fissures and Gills. — In nearly all adult Selachians there are five gill-openings in each side; Hexanchus and Heptanchus have respectively six and seven such openings. In addition to these, all of the skates and some of the sharks have a peculiar opening just behind the eyes, or at some point between these and the first branchial fissure, which makes a direct communication, for the most part of a large size, between the top of the head and the pharynx, and to which the terms "spiracle," "event," "Spritz-locher," "foramina temporalia," etc., have been applied.

In the youngest embryos of skates here described, we have found the number of gill-openings or branchial fissures seven on each side, all well defined except the last, which is the smallest of the series (figs. 4 and 4[a]). These are all in the same range from before backward, and at this stage the spiracle, as such, is not distinguished from the others. It is characteristic of the early embryos of all Selachians, to have developed, in connection with branchial apparatus, temporary gills, which are seen in the form of long and slender filaments projecting from the sides of the neck. They are generally described as coming out through the gill-openings, and as prolongations of the internal gills. Cornalia,† who has made a special study of these organs, so describes and figures them. We believe that, in consequence of not having seen embryos sufficiently young, he has been led into an error.

We have found them, when first formed, growing from the outer edge of the branchial arch (figs. 4[a] and 5), and at that time in no way connected with the branchial fissures. In the skate, the first and seventh arch had no fringes at any period, and of the five which had them, the fringes of the foremost ones were the longest, the hindmost being merely short, conical projections. As development advances, the bases of the fringes are gradually covered up, as it seems, by the growth of the portion of each arch in front of them, which is thus projected outward as the body

* Animal Kingdom, McMurtrie's translation, (New York, 1831,) Vol. II. p. 283.

† Sulle Branchie Transitorie dei Feti Plagiostomi. Memoria del Dottore Emilio Cornalia. 1856.

becomes thicker from side to side; the line of attachment of the fringe, which retains its original position, being thus buried between two adjoining arches.

From the fact that the temporary gills are formed before the permanent ones, and from the outer surface of the arch, it is obvious that they cannot be — as commonly described — prolongations of these last-mentioned breathing organs.

The fringes do not cover the whole border of the arch, but are confined to its central portion, and consist of from six to eight filaments each.

We have made no observations on the formation of the internal gills, and cannot therefore explain the connection which eventually exists between these and the fringes, and which at a later period correspond exactly with the descriptions usually given.

The existence of temporary branchial fringes, and their subsequent absorption, is one of the most remarkable characteristics of Selachians, and one in which they differ from all osseous fishes, unless it be the Lepidosiren.* All vertebrates, as embryos, agree in this, that they are in their early stages provided with "branchial fissures" and "arches," or, as they have sometimes been called, "visceral arches." Gills or gill fringes, either as temporary or permanent structures, are never formed in any scaly reptile, bird, or mammal.† Much confusion and misapprehension have arisen from the constant reiteration of the opinion put forth in the early days of embryology, that all vertebrates at one time have a branchial respiration, an error which is repeated by naturalists even at the present day. Among Batrachians some genera, as Menobranchus, Siren, Axolotl, etc., have external fringes permanently attached to their branchial arches, which are not known to be replaced by, or to coexist with, internal gills. They are their sole organs of respiration, for their lungs are too imperfect and rudimentary to have much physiological importance. In frogs, toads, and salamanders, the external gills are replaced by internal ones, and these in turn by lungs. Thus it will be seen that no Batrachian is permanently provided with internal gills.

Selachians and Batrachians agree in this, that their embryos have in their first stages external fringes growing from the outer surface of the gill arches, and these

* "In the *Lepidosiren annectens*, three small external branchial filaments project from the single opercular aperture on each side, and are long retained, if they be not permanent, in that remarkable osculant form between the osseous and the cartilaginous fishes." Owen, Lects. on Comp. Anat., Vol. II. p. 301. See also Jardine, Ann. Nat. Hist., Vol. VII., (1843,) and Peters, Müller's Archives (1845).

† The recent investigations of Lereboullet on the development of the lizard are, as regards this animal, to the same effect. "The branchial arches do not, in the evolution, pass through the same phases as those of fishes. They never become provided with fringes, and never perform the functions of respiratory organs." Annales des Sciences Naturelles, Tom. XVII., (1862,) p. 127.

fringes have the same structure in both.* The Selachians still further agree with frogs, toads, and salamanders, in the fact that the outer fringes are absorbed, and are replaced by internal gills. They differ from them, however, in the following particular. Selachians retain their internal gills permanently through life, while, if such exist at all in the Batrachians just mentioned, it is only during the larval stage, and they are soon replaced by lungs. Selachians may therefore be said to pass through stages analogous to the first and second stages of Anourous Batrachians and salamanders.

The other changes which the fissures pass through before the skate acquires its permanent form are as follows. The seventh fissure is closed up at a very early period, about the time that the dorsals are beginning to be formed. While the first arch bends and is drawn forward as already described in connection with the formation of the jaws, it at the same time becomes broader, so as to widen the distance between the mouth and the first fissure, or the second, after the first is partially closed. The inner part of the first closes up, while the outer remains open (fig. 5, *a*), is somewhat enlarged, and retains its relative position to the eye. It is very soon widely separated from the other fissures by the rapid growth of the intervening parts, and still further by the extension of the pectoral fins forward between this remnant of the first fissure and those behind it, the former being thus thrown to the upper, and the latter to the under surface. The unclosed portion of the first branchial fissure is thus converted into the spiracle.

The transformation thus described is of very great interest when compared with the changes which occur in the corresponding fissures of the air-breathing vertebrates, and enables us to establish an unexpected homology. Reichert,† in his most important investigations of the development of the gill arches ("visceral Bogen") of the pig, has shown that in this animal the first fissure is gradually separated from the others by the widening of the second arch, and for a time, even after all the others are closed up, forms a direct opening from the side of the neck into the pharynx. Afterwards it is

* Cornalia states that these respiratory fringes are not found in the "cotylophorus" sharks, as in Centrina, for in such the fœtus forms a direct communication with the oviduct of the parent, and the fringes are therefore unnecessary. This statement may be questioned with propriety, on the ground of analogy, unless it were based upon observations made upon very young embryos. This, however, does not appear to have been the case, for the figure of the fœtus referred to by him as evidence (see Carus, Entwickelung der Thiere im Allgemeine, Tab. VI. fig. 9) shows that the specimen was quite advanced, and has reached a period when the fringes might have been absorbed. It is quite probable that, as the young of such sharks have the advantage of a vitelline placenta, the fringes would disappear at a very early stage. See Cornalia, Sulle Branchie Transitorie dei Fèti Plagiostomi, (Nizza, 1856,) p. 22.

† Meckel's Archives, (1837,) p. 120.

divided into an outer and inner portion by a membranous septum; the former being the external auditory canal, and the latter the Eustachian tube and the cavity of the tympanum. It will thus be seen that the spiracle is not only a true branchial fissure in the first place, but that in the end it is homologous with the Eustachian tube and the outer auditory passage before these are separated from each other by the membrane of the tympanum.

Professor Huxley, in a series of lectures * on the Vertebrate Skeleton, in which the homologies and development of it are discussed with great ability, sets forth a somewhat different view with regard to the formation of the external ear, and maintains that the first step is similar to that in the case of the eyes and nose, viz. an "involution" or a "pushing in" of the integument. Professor Huxley's observations were made on the chick, and he arrives at the same conclusions as Remak, leaving us to infer that the auditory passage and Eustachian tube have no connection with the branchial fissures. We have gone over the same ground in the pig, and have found Reichert's observations, as mentioned above, fully confirmed.

The relation of the spiracle to the branchial fissures is still further shown by the fact that in some species, as in Scyllium and Læmargus, it, like the others, is provided with respiratory fringes. In the skate this is not the case, but in the adult a comb-like fold, resembling, and probably having the functions of, a gill, is found just within the spiracular opening.

The following is a general summary of the results contained in the preceding pages.

1. The yelk case is formed in the glandular portion of the oviduct, and is begun previously to the detachment from the ovary of the yelk which is to occupy it.

2. The embryo, before assuming its adult form, is at first eel-shaped, and then shark-shaped.

3. The embryo is for a short time connected with the yelk by means of a slender umbilical cord; the cord afterwards shortens, and the young skate remains in contact with the yelk until the end of incubation.

4. There are seven branchial fissures at first; the foremost of these is converted into the spiracle, which is the homologue of the Eustachian tube and the outer ear canal; the seventh is wholly closed up, and no trace remains; the others remain permanently open.

* Structure and Development of the Vertebrate Skeleton, London Lancet, July, 1863, p. 427, American reprint.

5. There are no temporary branchial fringes or filaments on the first and seventh arches; on the others the fringes are developed from the outer and convex portion of the arch, and are not at first prolongations of the internal gills.

6. The nostrils, as in all vertebrates, consist at first of pits or indentations in the integuments; secondly, a lobe is developed on the inner border of each; and finally, the two lobes become connected, and thus form the homologue of the fronto-nasal protuberance. The transitional stages of these correspond with the adult conditions of them in other species of Selachians.

7. The nasal grooves are compared with the nasal passages of air-breathing animals, and the cartilages on either side of these to the maxillary and intermaxillary bones.

8. The foremost part of the head is formed by the extension of the facial disk forward; while this extension is going on, the cerebral lobes change their position from beneath the optic lobes to one in front of them.

9. Two anal fins, one quite large and the other very small, are developed, but both are afterwards wholly absorbed.

10. The dorsals change position from the middle to the end of the tail. At the time of hatching, however, there is still a slender terminal portion of the tail, which is afterwards either absorbed or covered up by the enlarged dorsals, as they extend backward.

EXPLANATION OF THE FIGURES.

Fig. 1. Egg case, one half of the natural size, linear measurement; *a*, pouch for the yelk; *b b'*, openings for the inward and outward flow of water; *c*, spur; *d*, membrane formed by the interweaving of the lateral filaments.

Fig. 2. Eel-shaped embryo, connected with the yelk by a slender umbilical cord; *a*, omphalo-mesenteric artery; *c*, dorsals; *d*, anal.

Fig. 3. Under side of the yelk of the preceding specimen; *a*, the continuation of the artery seen in fig. 2, and connecting with the triangular terminal sinus.

Fig. 4. A more advanced embryo, showing at *a* and *b* the pectorals and ventrals; *d*, the temporary anal.

Fig. 4ᵃ. Head of the preceding enlarged; *b*, first branchial arch, without fringes; *d*, projection of the optic lobes; *e*, projection of the cerebral lobes; the open space between the first branchial arches is the mouth.

Fig. 5. Side view of the same; *a*, first branchial fissure, largest at its outer end; this enlarged portion corresponds with the future spiracle; *b*, the inner end; the first arch is in front of this fissure; *b'*, the second fissure, in front of which is the second arch, bearing a fringe; *c*, nasal fossa; *d*, projection of the optic lobes; *e*, cerebral lobes.

Fig. 6. A shark-shaped embryo; *c*, dorsals; *d d'*, anals. In this figure the embryo is represented as twisted on the yelk, through half a circle, consequently the artery is directed backward instead of forward.

Figs. 7, 8, 9. A more advanced embryo, seen from the side, from above, and from below; *a*, fig. 7, artery; *a a'*, figs. 8 and 9, pectoral fin; *b*, figs. 7 and 9, facial disk; *c*, figs. 8 and 9, ventrals; *c*, fig. 7, dorsals; *d*, figs. 7 and 9, anal; *e*, figs. 8 and 9, gill fringes.

Fig. 10. Head of figure 6, enlarged; *a*, nasal lobe; *b*, facial disk; *c*, upper lip.

Fig. 11. Newly-hatched skate; *a*, yelk-sack in the cavity of the abdomen, connecting with the intestine, *b*; *c*, embryonic portion of the tail which disappears in the adult; this corresponds with all that is behind the dorsals in the preceding figures.

Fig. 1.

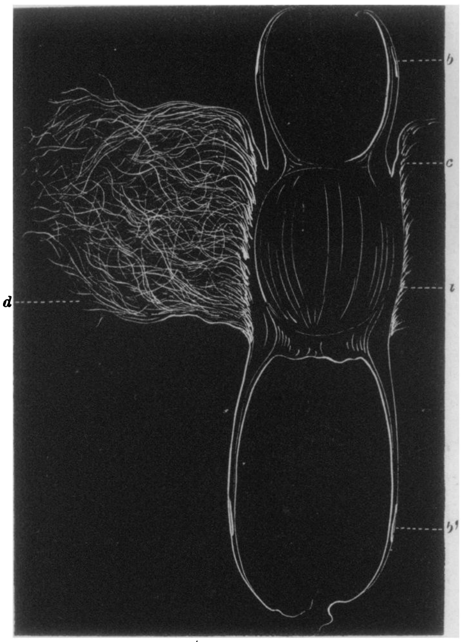


Fig. 2.

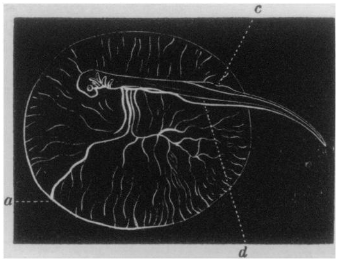


Fig. 6.

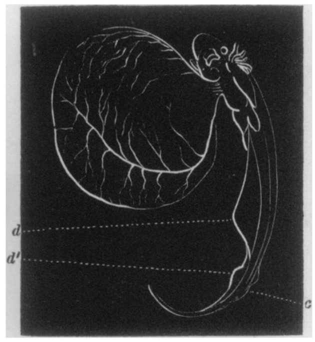


Fig. 3.

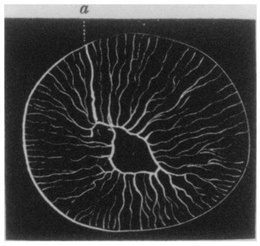


Fig. 4.

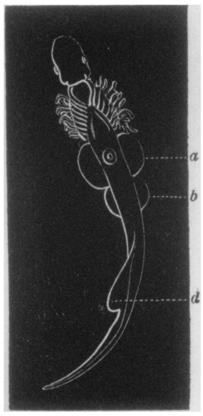


Fig. 4ª.

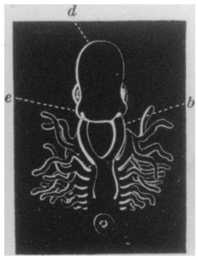


Fig. 7.

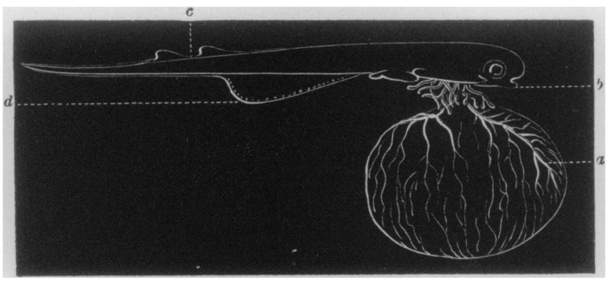


Fig. 11.

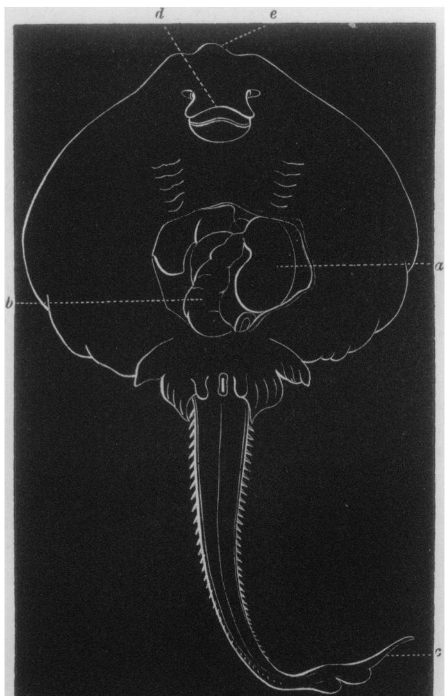


Fig. 9.

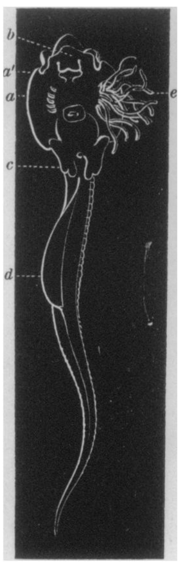


Fig. 8.

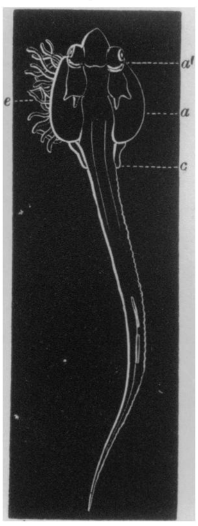


Fig. 5.

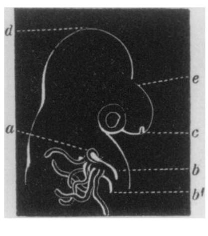
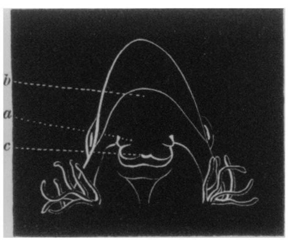


Fig. 10.



J. W. del.